

TRANSISTORIZED TV HORIZONTAL DRIVER DESIGN

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INTRODUCTION

In a transistor television receiver, the horizontal deflection coils in the yoke of the CRT are driven by the horizontal output transistor which operates as a switch. A simplified circuit is shown in Fig. 1. During the "on" period, the transistor provides a low resistance connection to ground, allowing the choke current and yoke current to increase. At the end of the trace period, the horizontal output device turns "off", which initiates retrace. The current in the yoke reverses in an oscillatory mode (the choke and yoke resonate C_1), and a large positive voltage (flyback pulse) appears at the collector of the transistor. When this voltage reaches zero (actually, the forward voltage drop of the damper diode), the diode conducts placing a low series resistance in the loop. The yoke current, which is now negative, would decrease linearly except for the capacitor C_2 , which places an "S" correction in the yoke current waveform. Before the current in the yoke reverses and the diode cuts off, the transistor is turned on again to allow the yoke current to increase in the positive direction until the end of trace. Turning off the transistor starts the repetition of the cycle.

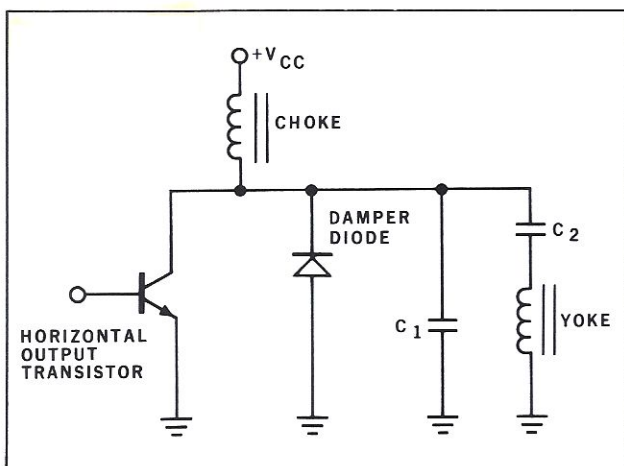


Fig. 1. Horizontal output stage.

HORIZONTAL OUTPUT DRIVE REQUIREMENTS

Fig. 2 shows that the collector current in the output transistor follows an approximate ramp function which is composed of the yoke current and the choke current. During the conduction period, the transistor must be supplied sufficient base drive current to keep it in full saturation to the end of trace. At the beginning of the retrace, the transistor is turned off rapidly to minimize device dissipation. This is accomplished by applying a reverse voltage, less than V_{EBO} , to the base which removes its stored charge.

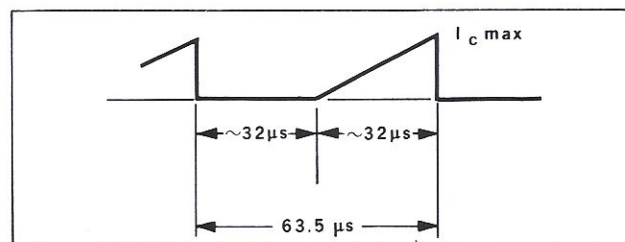


Fig. 2. Collector current in horizontal output transistor.

DRIVER CIRCUIT

A simple circuit which supplies the drive requirements for the horizontal output transistor is shown in Fig. 3.

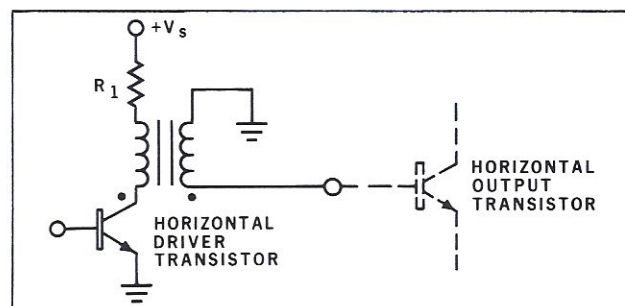


Fig. 3. Horizontal driver stage.

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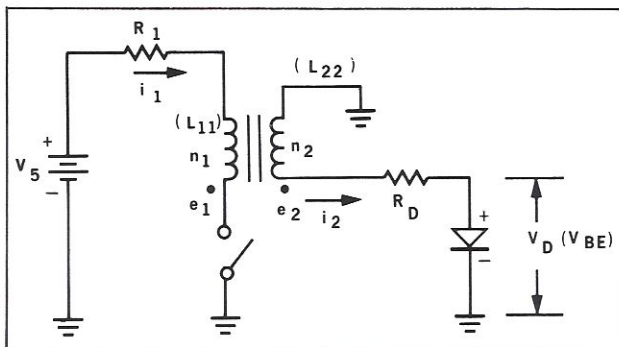


Fig. 4. Equivalent circuit of driver.

An equivalent circuit is given in Fig. 4. The driver transistor is represented by a diode with a forward drop, V_D , in series with a resistance, R_D .

The waveforms associated with the driver circuit are shown in Fig. 5. During time T_1 the switch is closed (Q_1 saturated) and current flows in the primary side of the transformer. The voltage induced in the secondary side back-biases the diode. This negative voltage removes the charge from the base of the horizontal output transistor at the beginning of retrace. At the beginning of time T_2 , the switch opens and the energy stored in the transformer supplies a secondary current, I_{2max} . During T_2 , I_2 decreases to I_{2min} , at which time Q_1 turns on again, thus repeating the cycle.

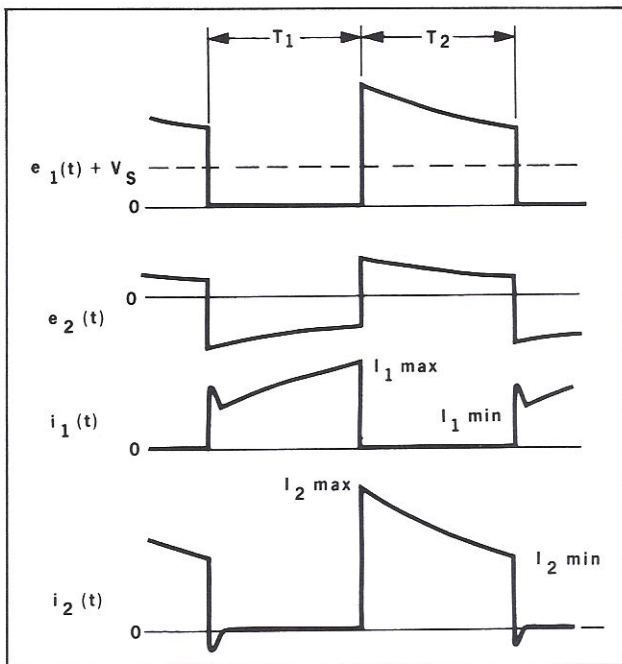


Fig. 5. Driver waveforms.

PRACTICAL DESIGN

The design of the driver stage for a small screen receiver operated from a 12-volt supply will be given to illustrate a design procedure. Equations used have been developed in the appendix.

The following data is known:

$$V_D = 1.2 \text{ v} \quad (\text{equivalent input representation of output transistor})$$

$$R_2 = R_D = 0.2 \Omega$$

$$I_{2min} = 1 \text{ A} \quad (\text{base drive required at end of trace})$$

$$T_1 = 24 \mu\text{sec}$$

$$T_2 = 39.5 \mu\text{sec}$$

$$V_S = 10 \text{ v}$$

Further, the following arbitrary criteria are given:

$$I_{2max} = 1.5 I_{2min}$$

$$I_{1max} R_1 = 0.3 V_S = K V_S$$

From Equation 6 in the appendix:

$$L_{22} = 115 \mu\text{h}^*$$

The transformer turns ratio, n , and the resistance, R_1 , are calculated using Equations 12 and 14 which gives

$$n = 3.2$$

$$R_1 = 6.3 \Omega$$

Finally, from Equation 8

$$L_{11} = 1.15 \text{ mh}^*$$

The maximum primary current from Equation 7 is

$$I_{1max} = 0.48 \text{ A}$$

This current is supplied by a 2N3567 driver transistor which is an epoxy-encapsulated high-current switch. The complete circuit is shown in Fig. 6.

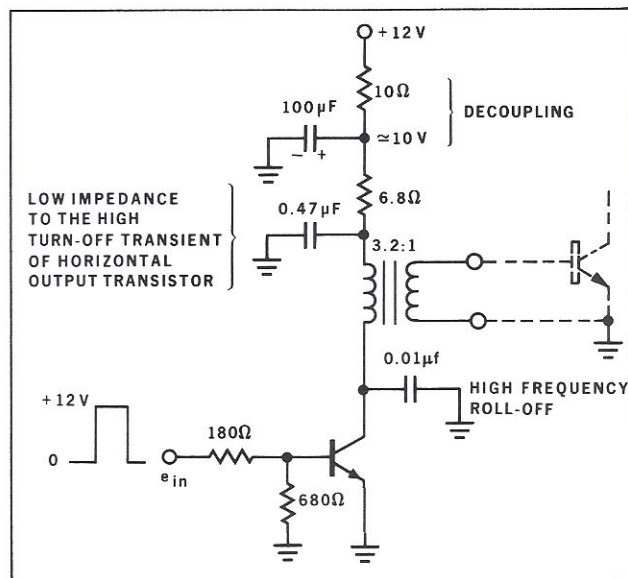


Fig. 6. Circuit of horizontal driver stage.

*Note: In the construction of the transformer, attention must be given to core characteristics and gapping to ensure that it does not saturate at maximum current conditions.

APPENDIX -- DRIVER ANALYSIS

In the following analysis, equations are derived for the waveforms associated with the driver stage. See Figs. 3, 4, and 5.

In each period, the current will change exponentially. When the starting point, the time constant, and the end point of an exponential curve are known, the equation for the curve can be written as:

$$\text{Function of time} = \text{End value} + (\text{Initial value} - \text{End value}) \exp \frac{-t}{\text{Time Constant}} \quad (1)$$

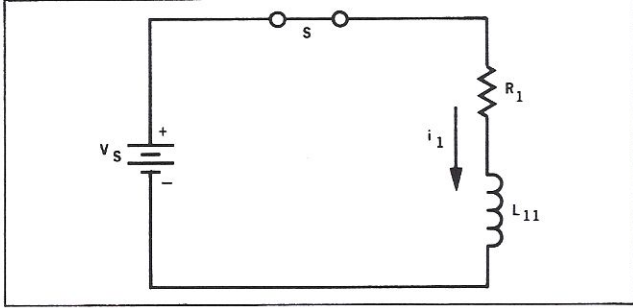


Fig. 7. Equivalent circuit during time T_1 .

During time T_1 , (switch closed) the equivalent circuit in Fig. 7 holds. Let the initial value be $I_{1\min}$. The time constant is

$$T_1 = \frac{L_{11}}{R_1}$$

and the end value to which the current i_1 tends to go is $\frac{V_S}{R_1}$ (steady state value). Therefore,

$$i_1(t) = \frac{V_S}{R_1} + \left(I_{1\min} - \frac{V_S}{R_1} \right) \exp \frac{-tR_1}{L_{11}} \quad (2)$$

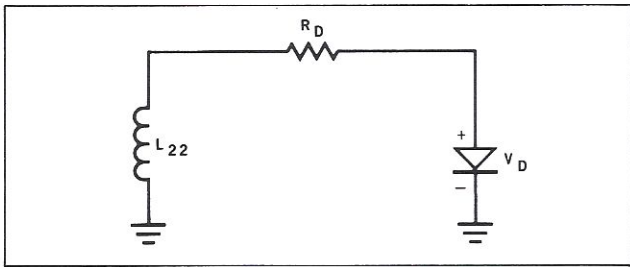


Fig. 8. Equivalent circuit during time T_2 .

The equivalent circuit during time T_2 is given in Fig. 8. The equation for $i_2(t)$ is derived in the same way as $i_1(t)$. The diode is considered to be a battery with voltage V_D . Therefore:

$$i_2(t) = -\frac{V_D}{R_D} + \left(I_{2\max} + \frac{V_D}{R_D} \right) \exp \frac{-tR_D}{L_{22}} \quad (3)$$

From Equations 2 and 3, the following equations can be written:

$$I_{1\max} = \frac{V_S}{R_1} - \left(\frac{V_S}{R_1} - I_{1\min} \right) \exp \frac{-T_1 R_1}{L_{11}} \quad (4)$$

and

$$I_{2\min} = -\frac{V_D}{R_D} + \left(I_{2\max} + \frac{V_D}{R_D} \right) \exp \frac{-T_2 R_D}{L_{22}} \quad (5)$$

Therefore:

$$L_{22} = \frac{T_2 R_D}{\ln \left(I_{2\max} + \frac{V_D}{R_D} \right) - \ln \left(I_{2\min} + \frac{V_D}{R_D} \right)} \quad (6)$$

Currents I_1 and I_2 are related as follows:

$$\frac{I_{2\max}}{I_{1\max}} = \frac{I_{2\min}}{I_{1\min}} = n \quad (7)$$

Also,

$$\frac{L_{11}}{L_{22}} = n^2 \quad (8)$$

Substituting L_{11} by $L_{22} n^2$, $I_{1\max}$ by $\frac{I_{2\max}}{n}$, and $I_{1\min}$ by $\frac{I_{2\min}}{n}$ in Equation 4 and rearranging gives:

$$\frac{I_{2\max} R_1}{n} - V_S = \left(\frac{I_{2\min} R_1}{n} - V_S \right) \exp \frac{T_1 R_1}{L_{22} n} \quad (9)$$

Dividing Equation 5 by Equation 9

$$\frac{I_{2\min} R_D + V_D}{\frac{I_{2\max} R_1}{n} - V_S} = \frac{I_{2\max} R_D + V_D}{\frac{I_{2\min} R_1}{n} - V_S} \exp \left(\frac{T_1 R_1}{n} - T_2 R_D \right) \frac{1}{L_{22}} \quad (10)$$

The maximum voltage drop across R_1 is $\frac{I_{2\max} R_1}{n}$. This can be expressed as a fraction of the supply voltage:

$$\frac{I_{2\max} R_1}{n} = K V_S \quad (11)$$

where $0 < K < 1$. A low value of K will make the circuit less sensitive to supply voltage variations but would increase the power dissipation in the driver stage. The value selected by the designer will be a compromise involving these two factors.

Defining the ratio $\frac{R_1}{n}$ as A :

$$A \triangleq \frac{R_1}{n} = \frac{K V_S}{I_{2\max}} \quad (12)$$

Placing the quantity A in Equation 10 yields

$$\frac{I_{2\min} R_D + V_D}{I_{2\max} A - V_S} = \frac{I_{2\max} R_D + V_D}{I_{2\min} A - V_S} \exp \frac{1}{L_{22}} \left(\frac{T_1}{n} A - T_2 R_D \right) \quad (13)$$

This is solved for n :

$$n = \frac{A T_1}{T_2 R_D + L_{22} \ln \left(\frac{I_{2\min} R_D + V_D}{I_{2\max} A - V_S} \times \frac{I_{2\min} A - V_S}{I_{2\max} R_D + V_D} \right)} \quad (14)$$

